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Rocha et al.

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(54) **INCREMENTAL MOUNT FRAMEWORK**

(71) Applicant: **Facebook, Inc.**, Menlo Park, CA (US)

(72) Inventors: **Lucas Almeida Rocha**, Bromley (GB); **Marco Cova**, London (GB)

(73) Assignee: **Facebook, Inc.**, Menlo Park, CA (US)

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G06F 3/0481	(2013.01)
G06F 9/451	(2018.01)
G06F 12/0893	(2016.01)

(52) **U.S. Cl.**

CPC ***G06F 3/0485*** (2013.01); ***G06F 3/0481*** (2013.01); ***G06F 9/451*** (2018.02); ***G06F 12/0893*** (2013.01)

(58) **Field of Classification Search**

CPC G06F 3/0485; G06F 9/451; G06F 3/0481; G06F 12/0893

See application file for complete search history.

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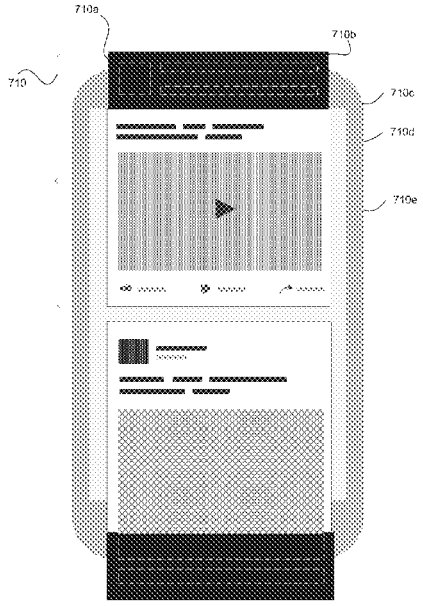
Primary Examiner — James T Tsai
(74) *Attorney, Agent, or Firm* — FisherBroyles, LLP

(57) **ABSTRACT**

Systems and methods directed to improve the responsiveness of an application's UI and improve a user's experience are disclosed. In particular, the systems and methods implement layout and rendering of UI components in a mobile application as two independent steps: layout and mount. During the layout step, attributes related to a layout are identified. For example, during the layout step, a list of UI components in each container, and their respective sizes and positions are identified. The layout result is then used in the mount step to create an actual view hierarchy to be rendered on screen once the component becomes visible. As result of this decoupling of layout operations from the rendering operations, the CPU-intensive measure and layout operations can be moved to the background thread, saving milliseconds.

20 Claims, 16 Drawing Sheets



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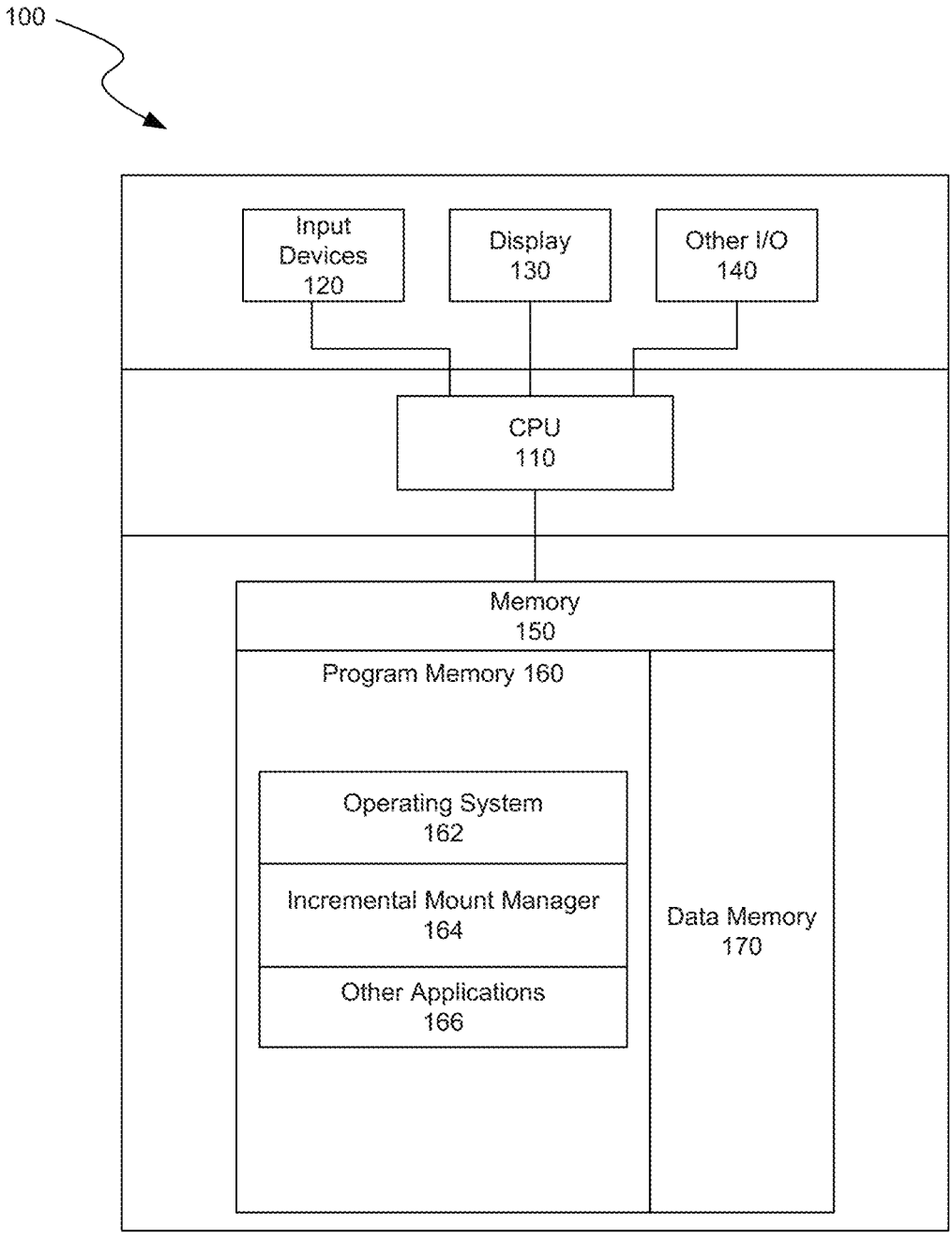

100
Input Devices 120
Display 130
Other I/O 140
CPU 110
Memory 150
Program Memory 160
Operating System 162
Incremental Mount Manager 164
Other Applications 166
Data Memory 170

FIG. 1

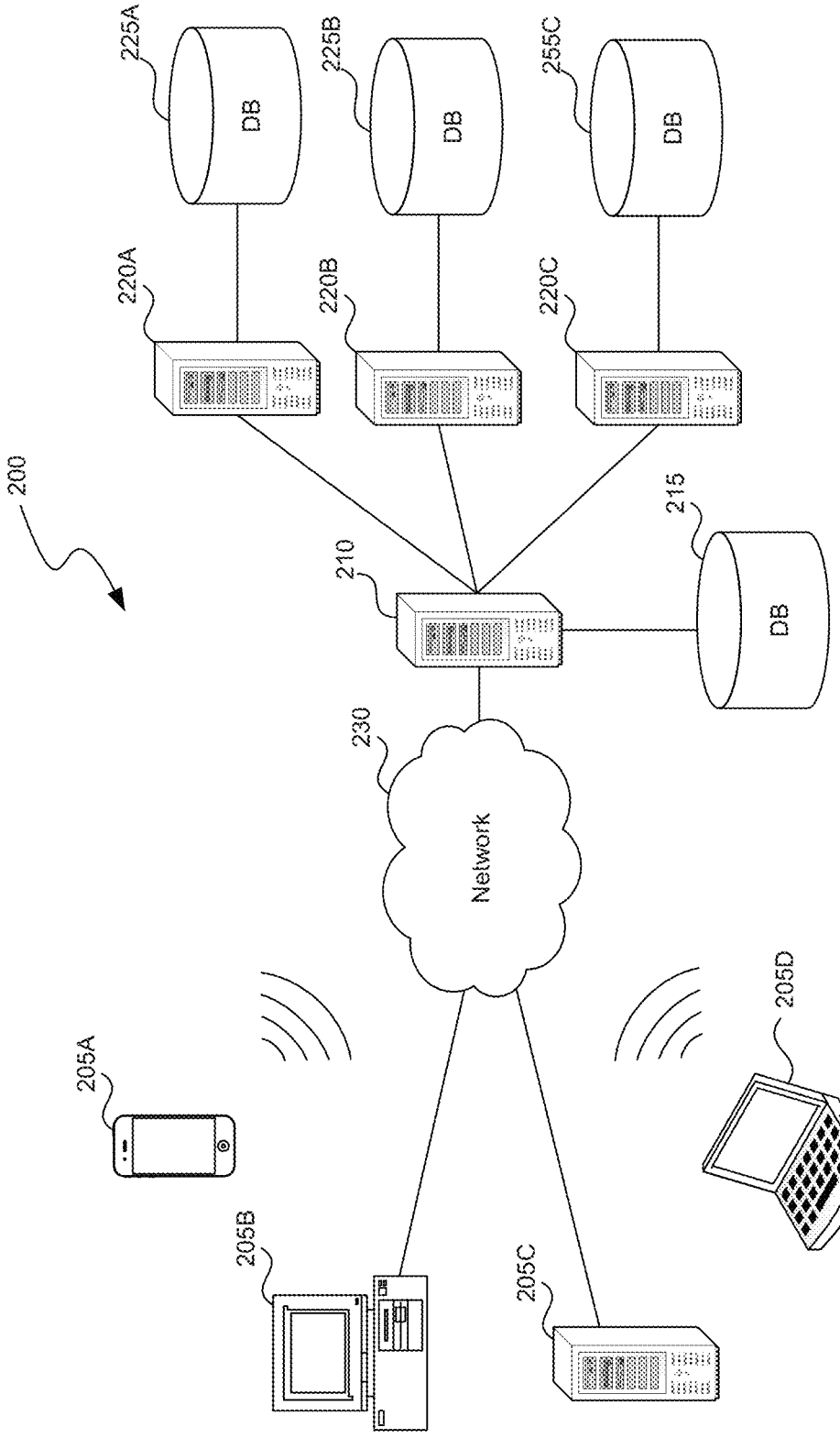

200
225A
DB
225B
DB
255C
DB
220A
220B
220C
215
DB
210
230
Network
205A
205B
205C
205D

FIG. 2

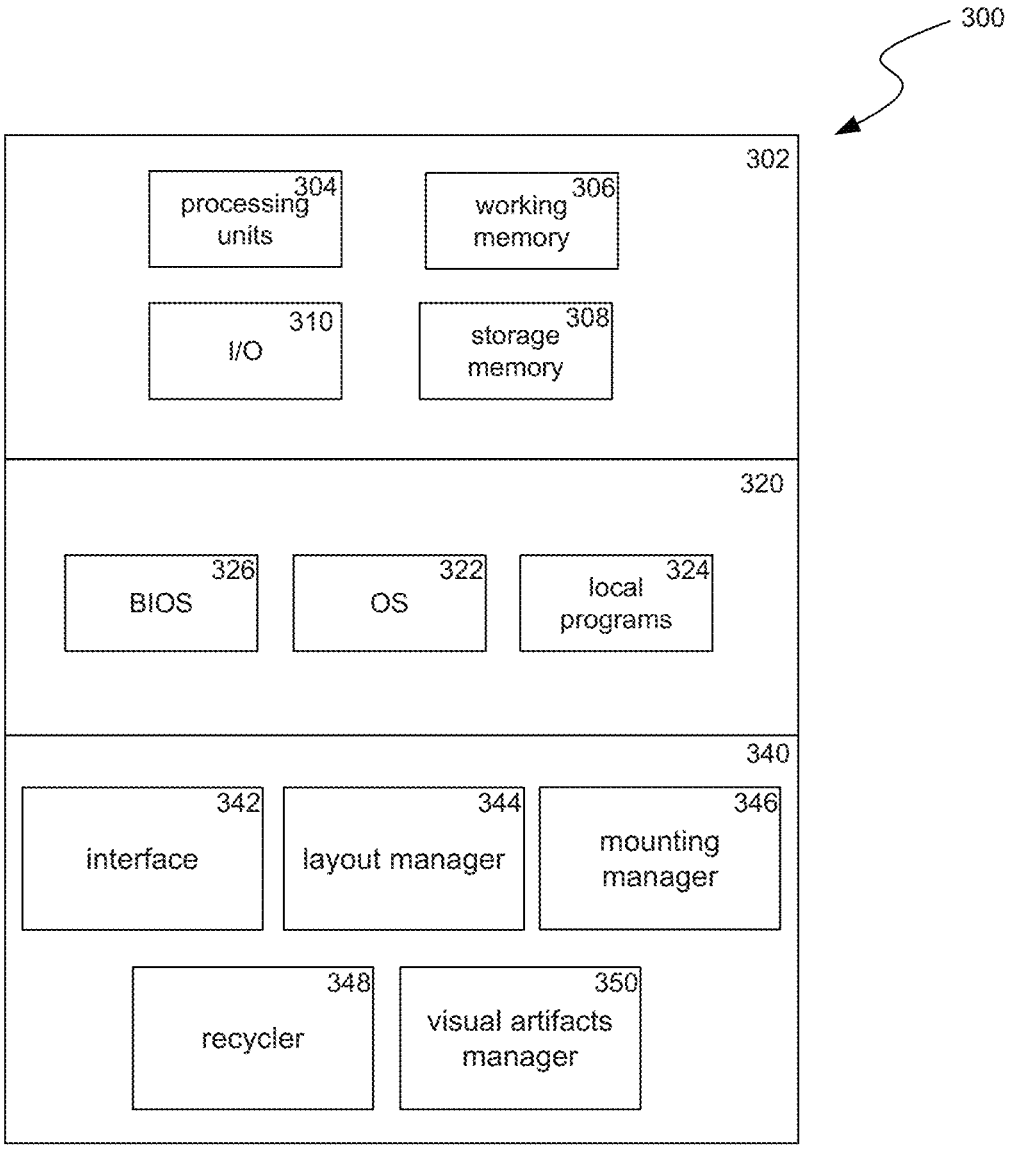

300
302
processing units
304
working memory
306
I/O
310
storage memory
308
320
BIOS
326
OS
322
local programs
324
340
interface
342
layout manager
344
mounting manager
346
recycler
348
visual artifacts manager
350

FIG. 3

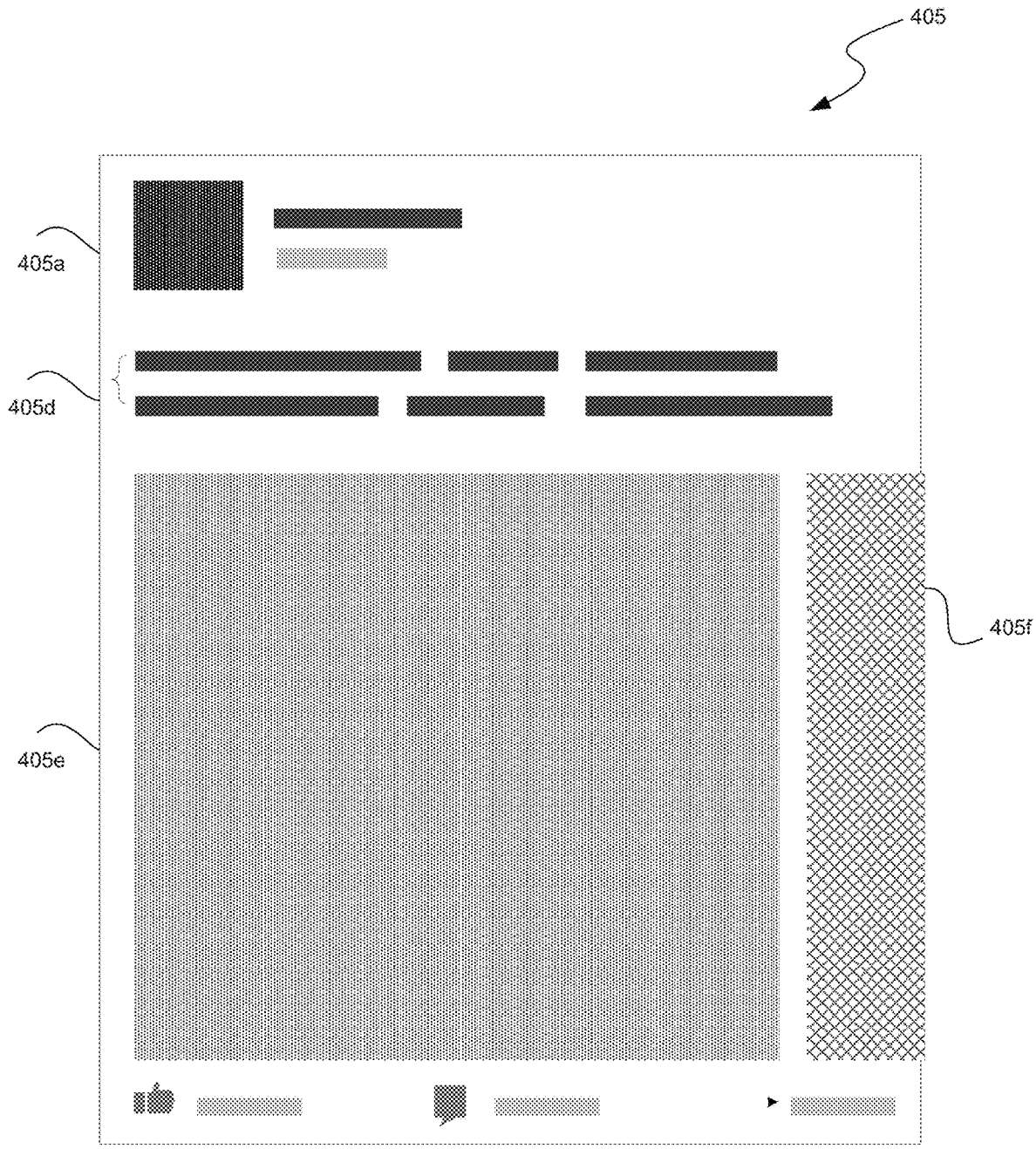


FIG. 4A

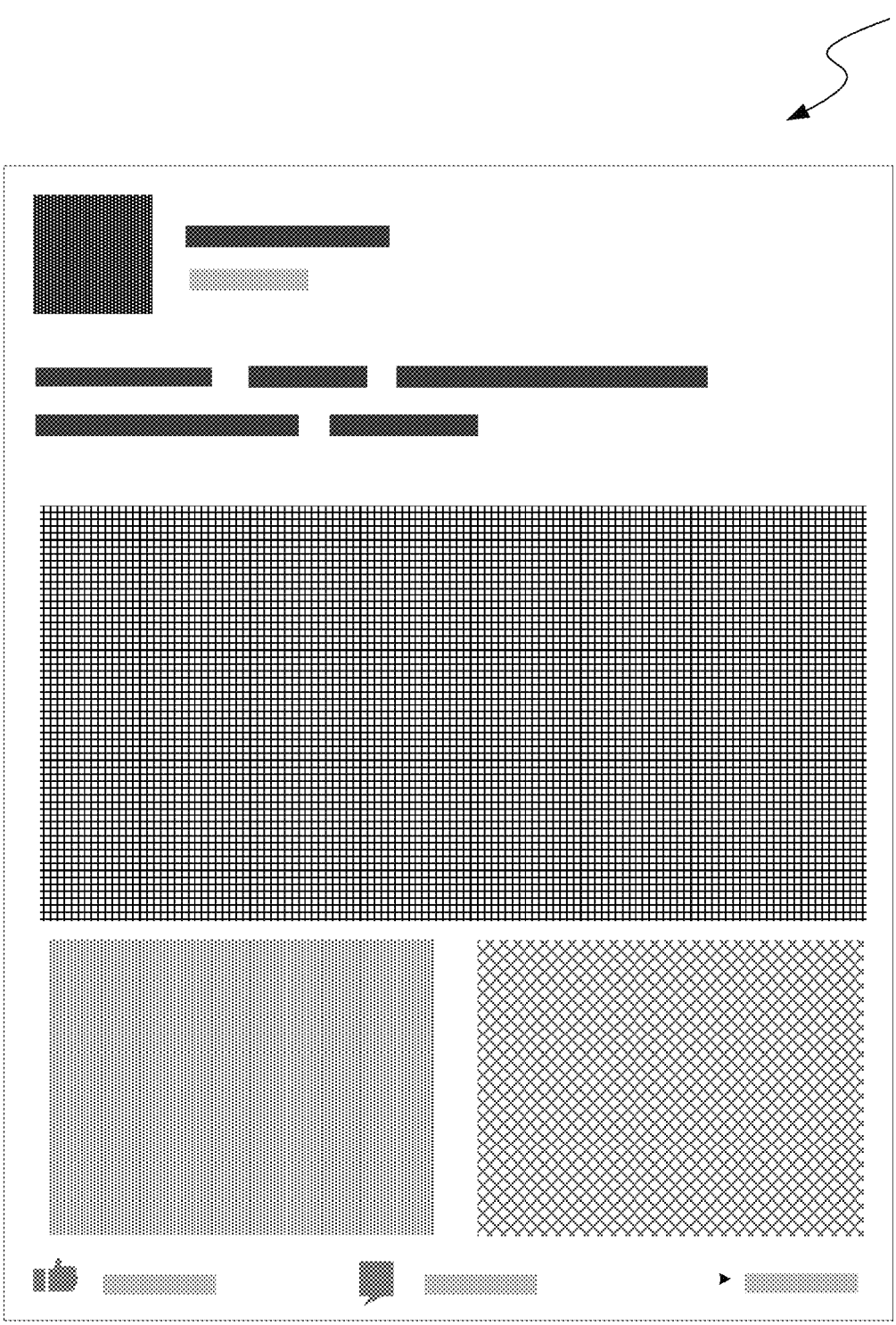


FIG. 4B

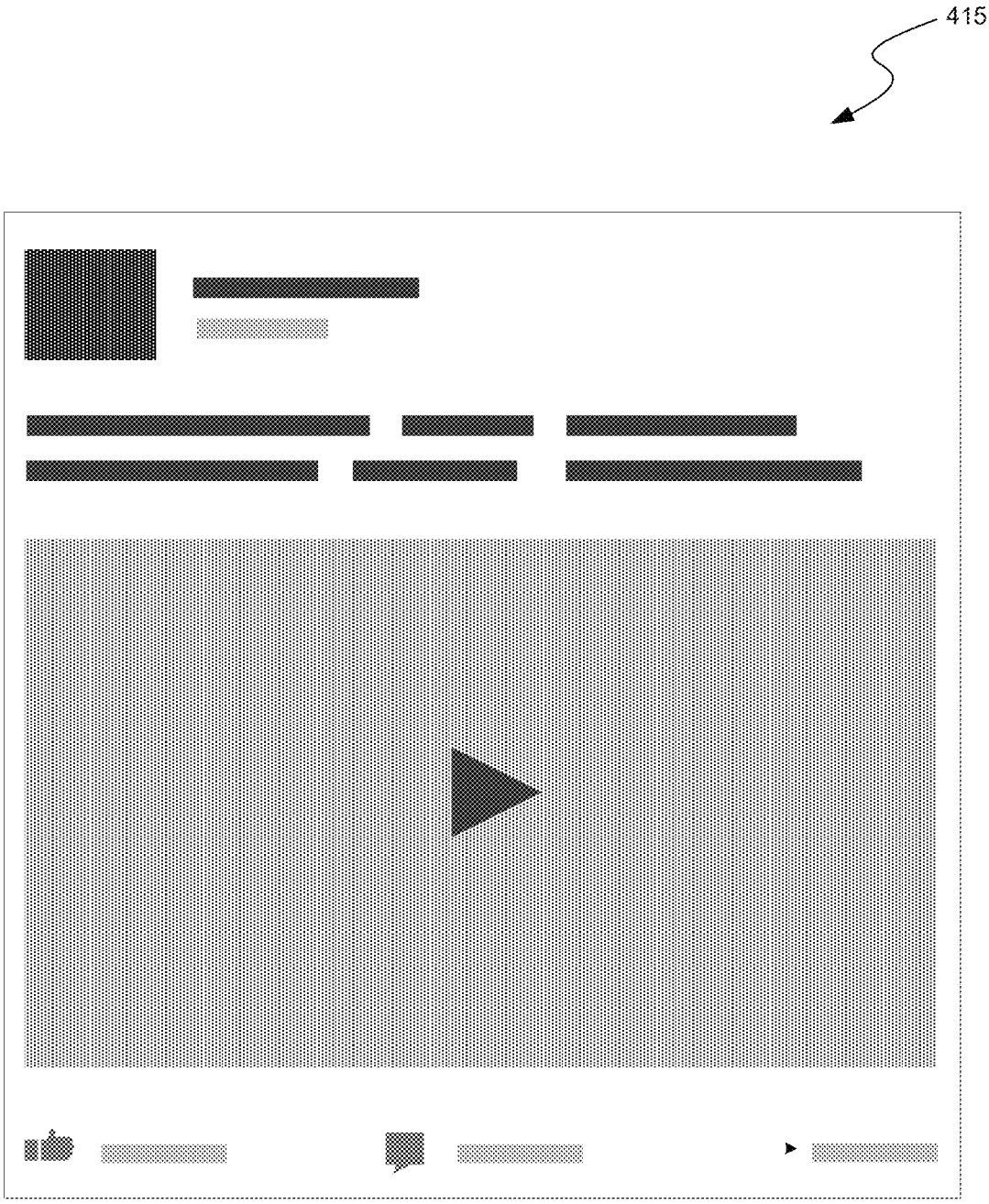


FIG. 4C

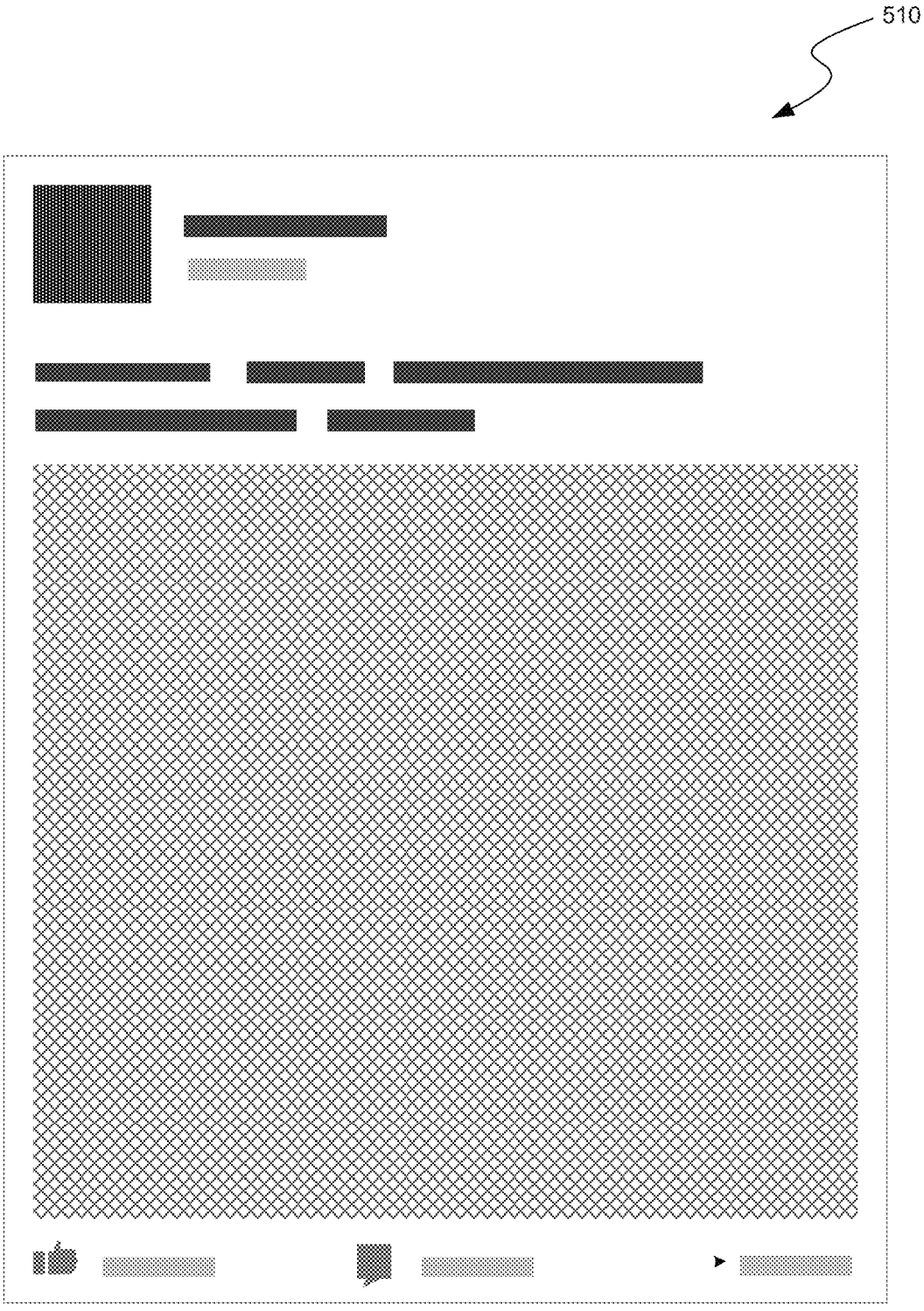


FIG. 5

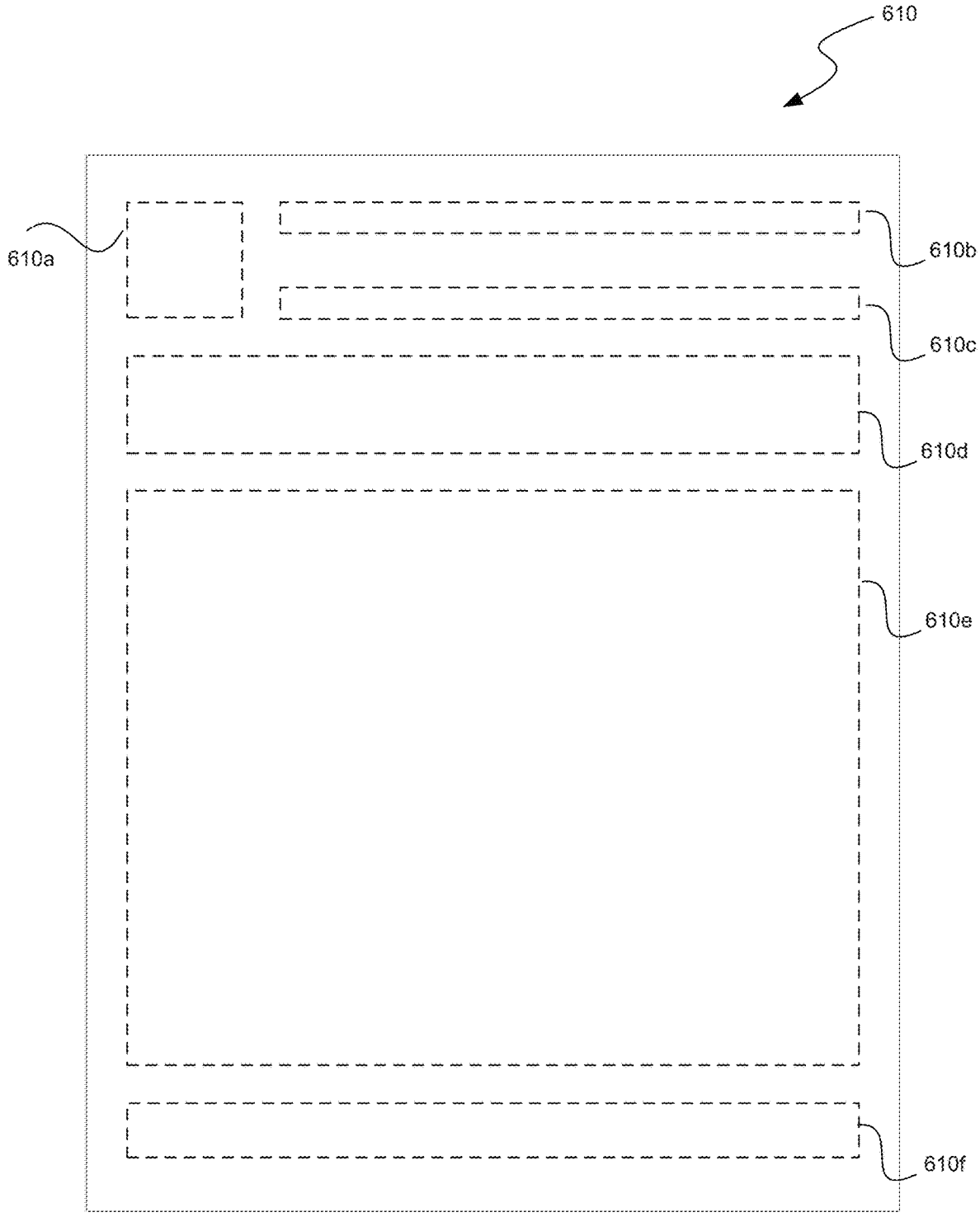


FIG. 6

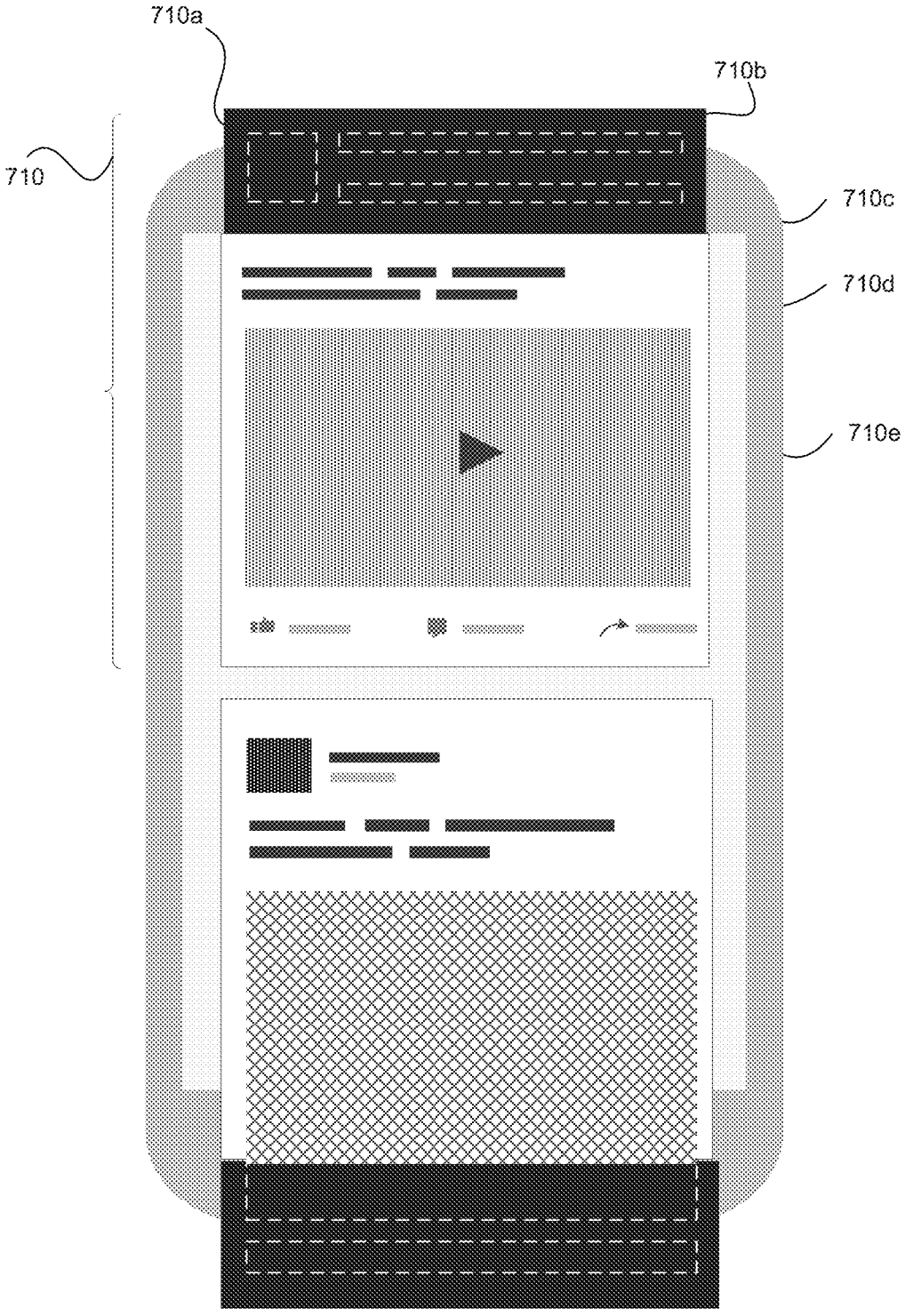
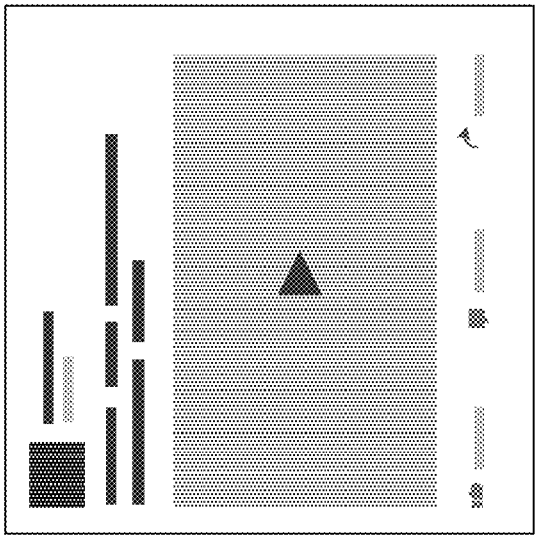
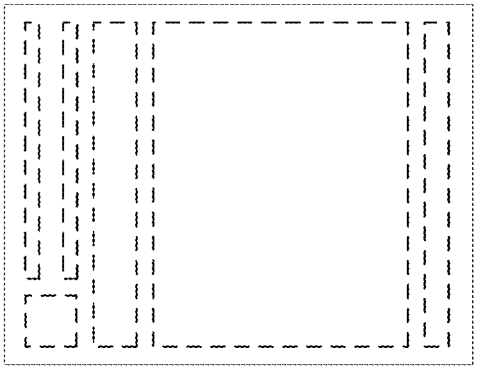


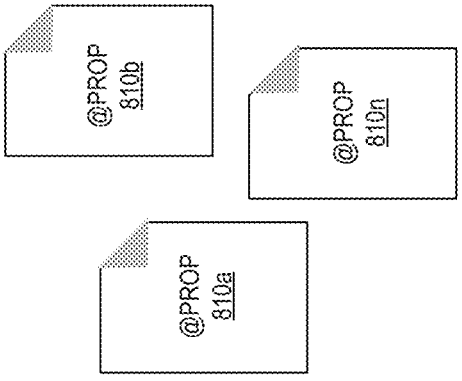
FIG. 7



Mount
820



Layout
815



Artifacts
810

FIG. 8

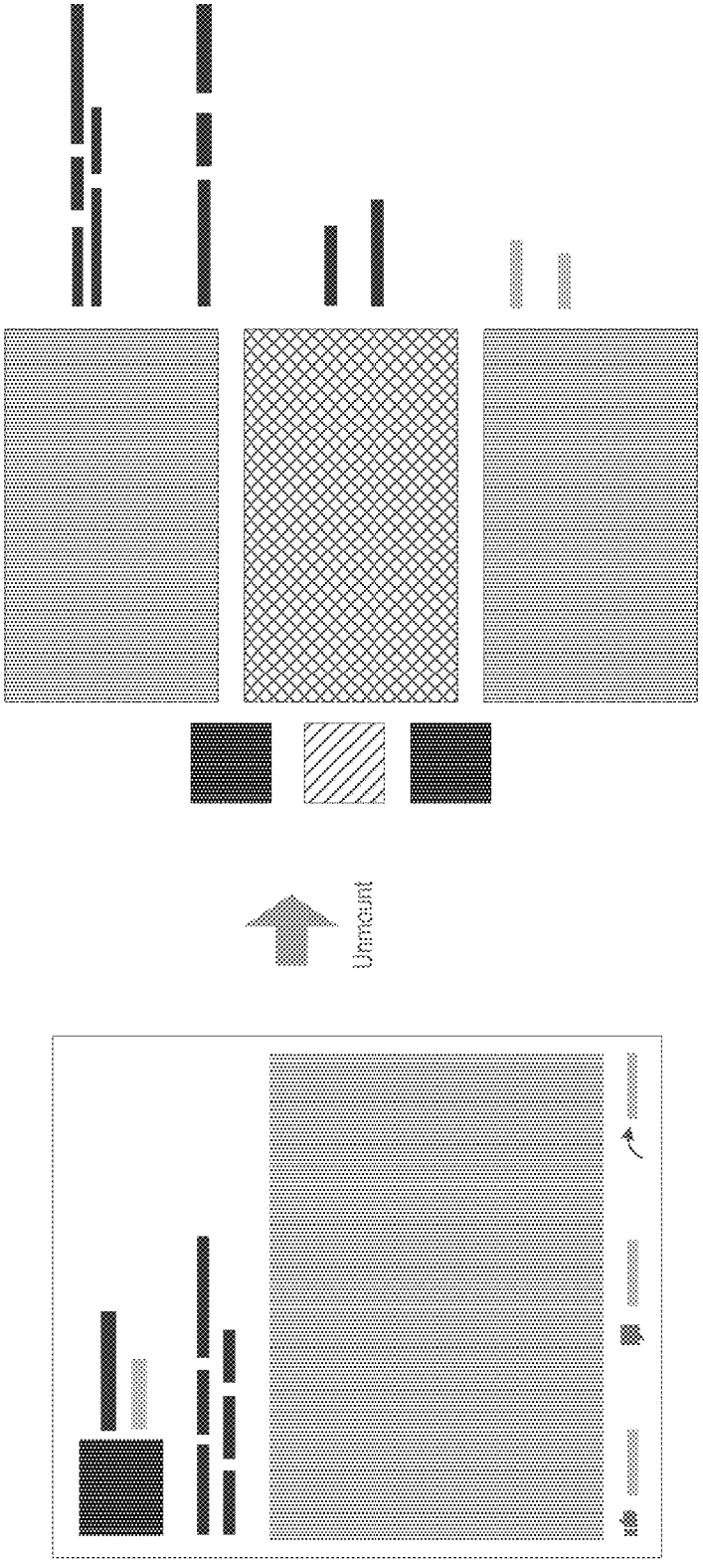


FIG. 9

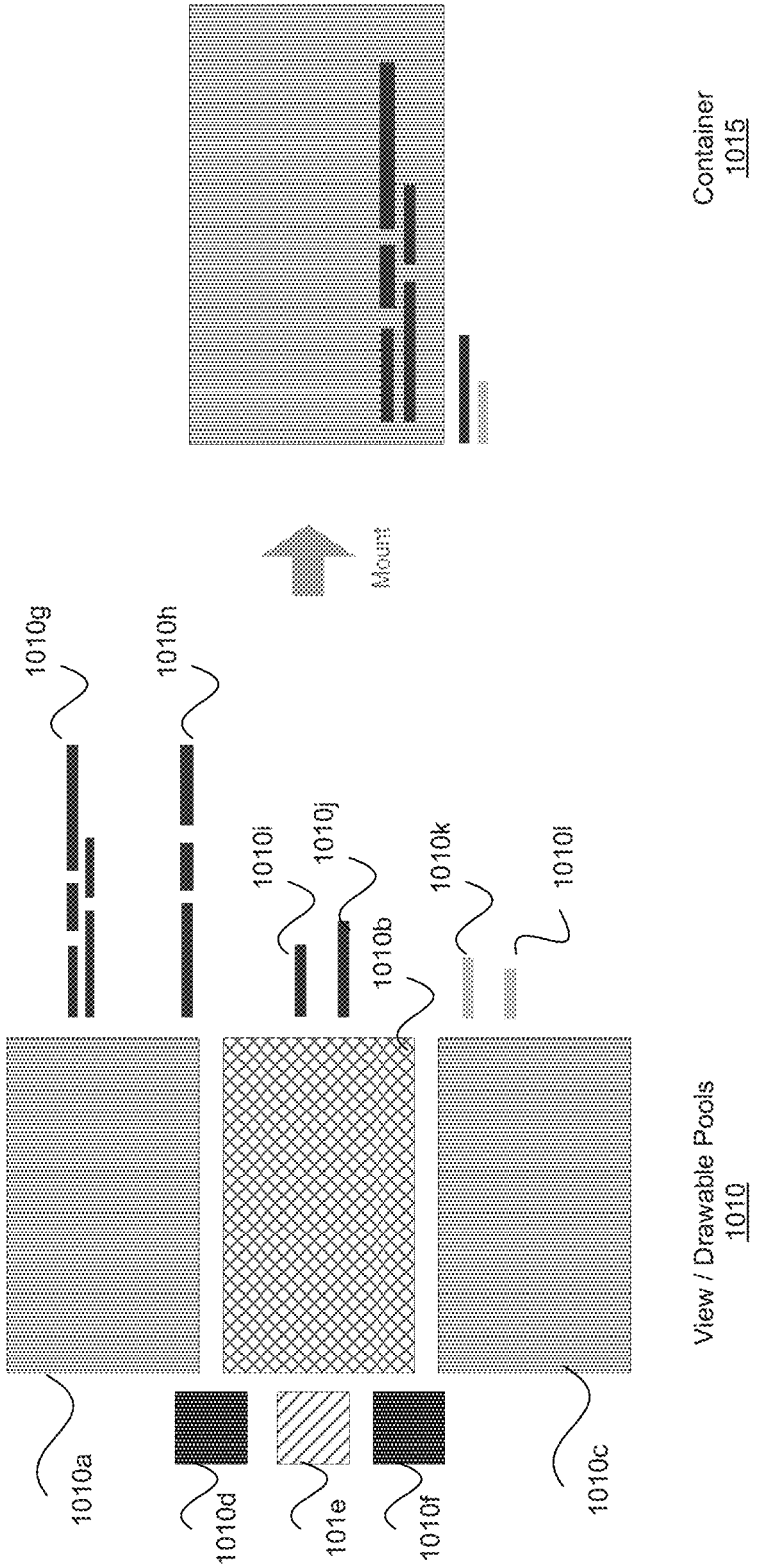

Container
1015
Mount
1010g
1010h
1010i
1010j
1010k
1010l
1010b
1010a
1010d
101e
1010f
1010c
View / Drawable Pools
1010

FIG. 10

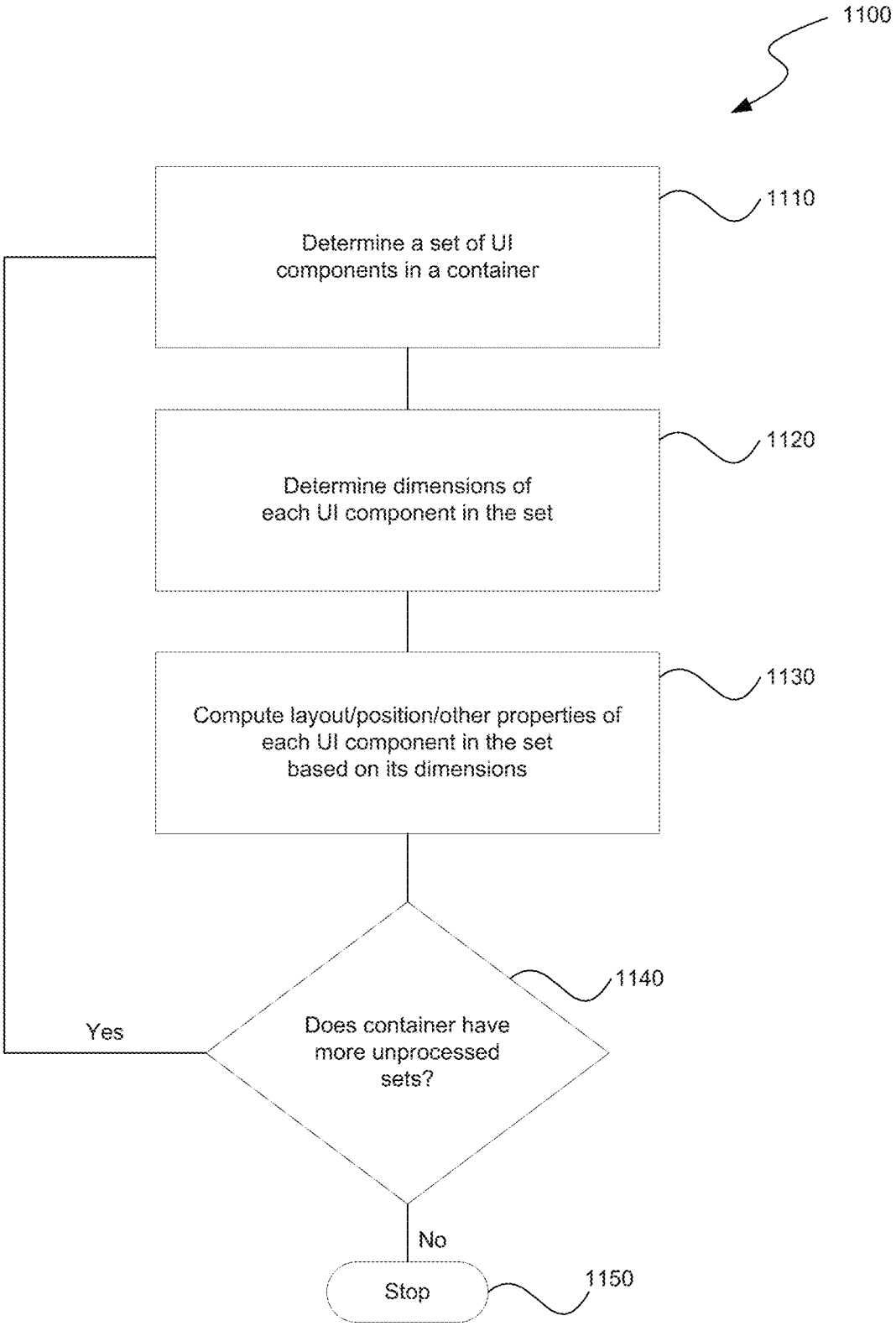

1100
Determine a set of UI components in a container
1110
Determine dimensions of each UI component in the set
1120
Compute layout/position/other properties of each UI component in the set based on its dimensions
1130
Does container have more unprocessed sets?
1140
Yes
No
Stop
1150

FIG. 11

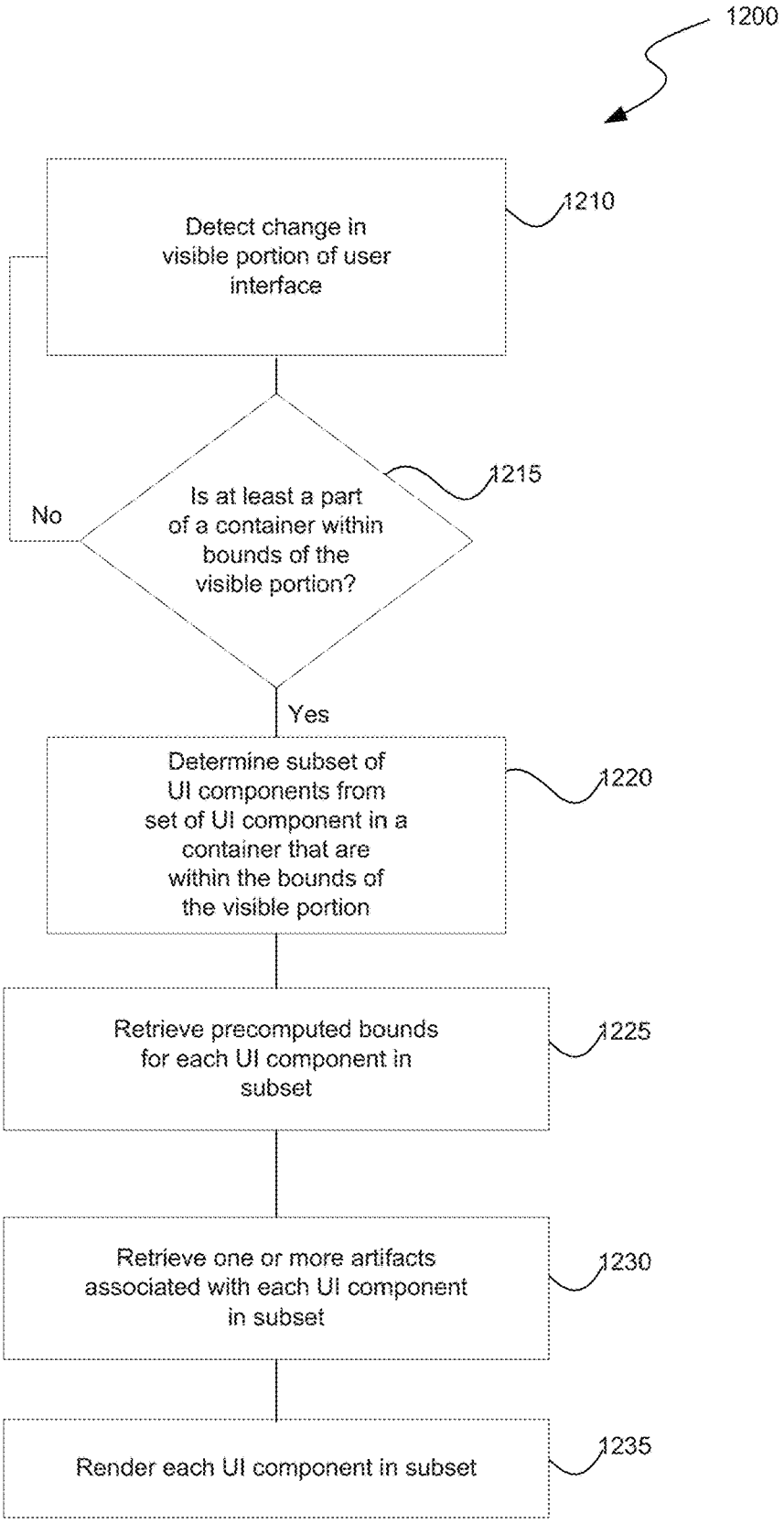

1200
Detect change in visible portion of user interface
1210
Is at least a part of a container within bounds of the visible portion?
1215
No
Yes
Determine subset of UI components from set of UI component in a container that are within the bounds of the visible portion
1220
Retrieve precomputed bounds for each UI component in subset
1225
Retrieve one or more artifacts associated with each UI component in subset
1230
Render each UI component in subset
1235

FIG. 12

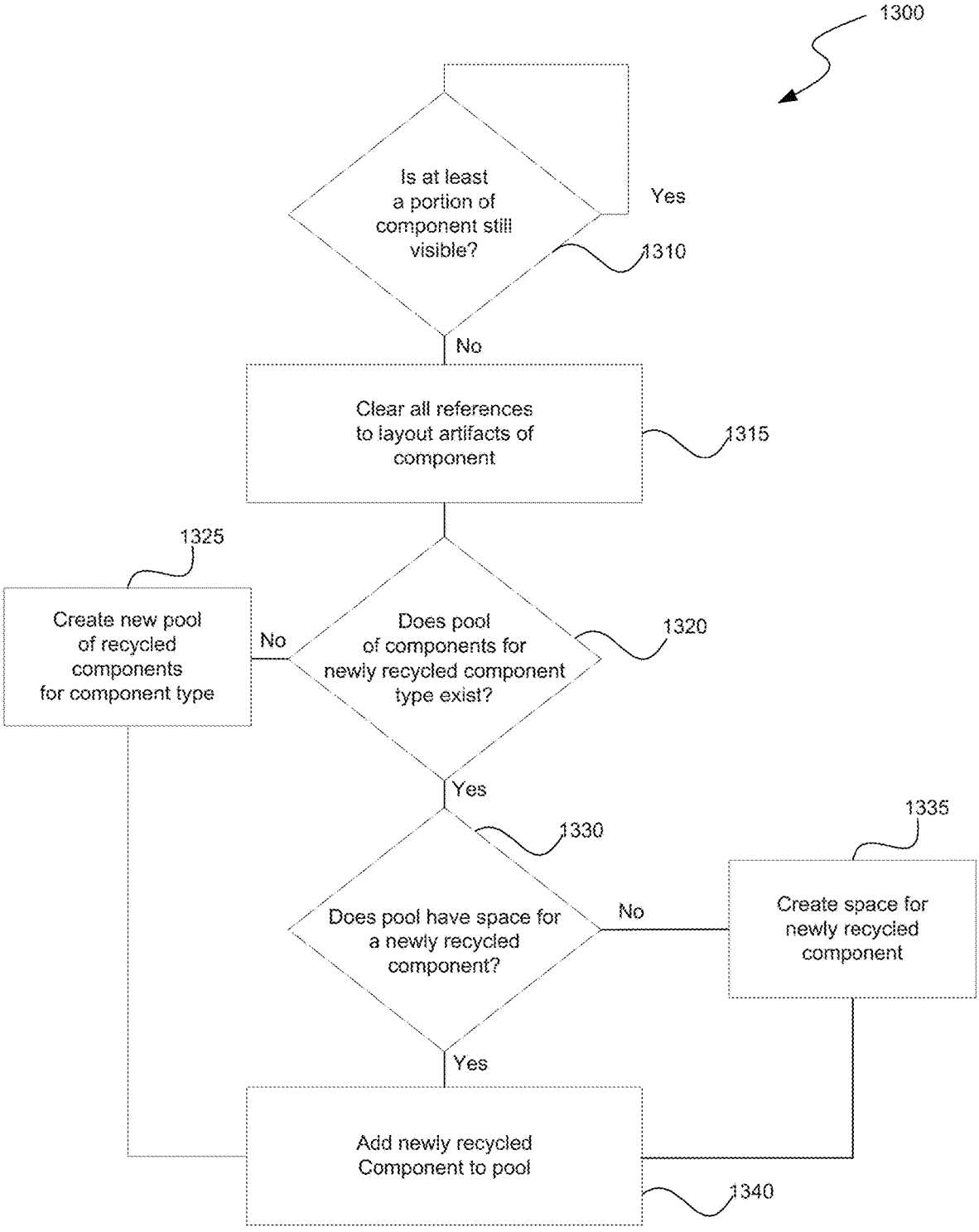

1300
Is at least a portion of component still visible?
1310
Yes
No
Clear all references to layout artifacts of component
1315
1325
Create new pool of recycled components for component type
No
Does pool of components for newly recycled component type exist?
1320
Yes
1330
1335
Does pool have space for a newly recycled component?
No
Create space for newly recycled component
Yes
Add newly recycled Component to pool
1340

FIG. 13

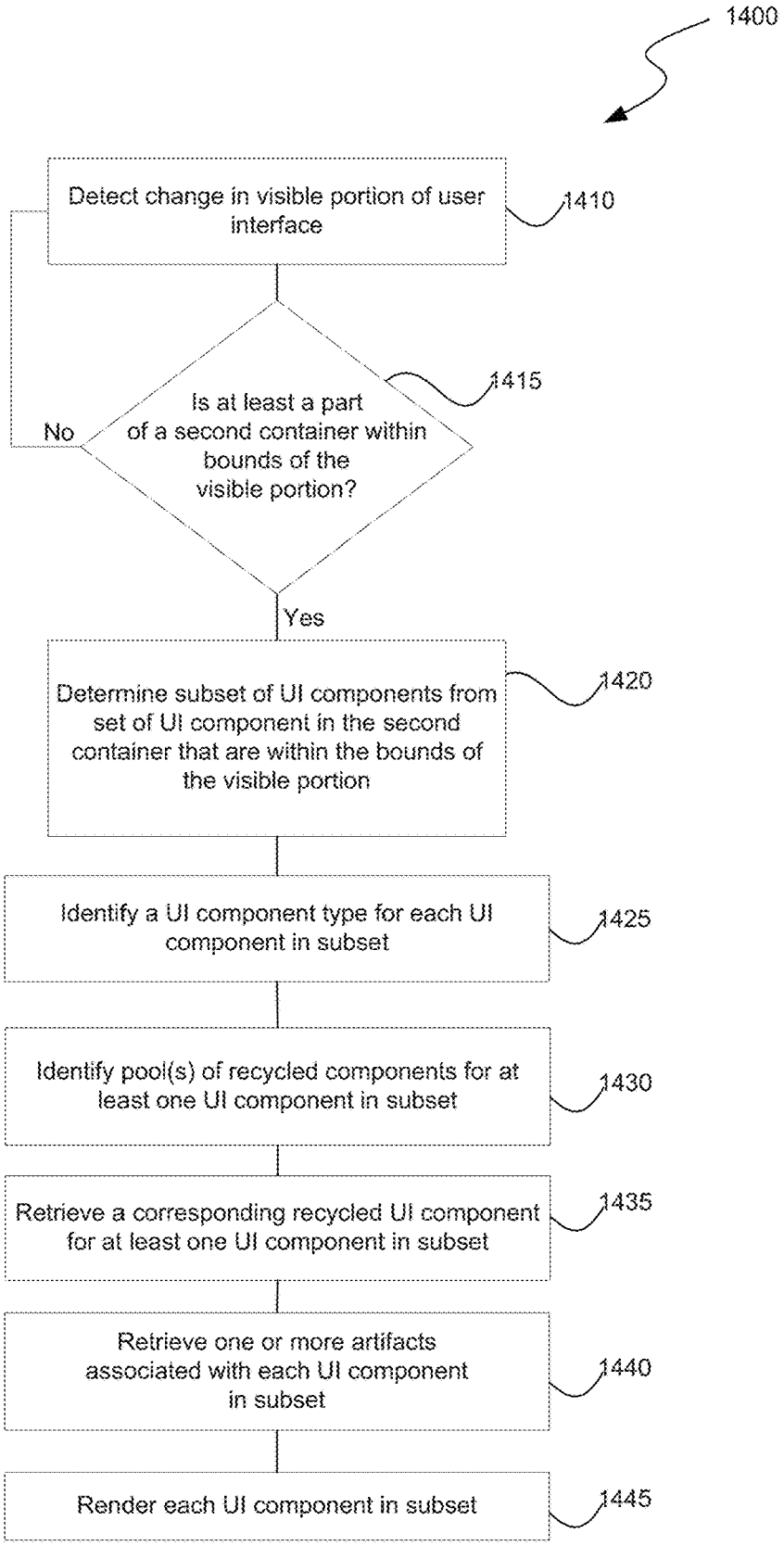

1400
Detect change in visible portion of user interface
1410
Is at least a part of a second container within bounds of the visible portion?
1415
No
Yes
Determine subset of UI components from set of UI component in the second container that are within the bounds of the visible portion
1420
Identify a UI component type for each UI component in subset
1425
Identify pool(s) of recycled components for at least one UI component in subset
1430
Retrieve a corresponding recycled UI component for at least one UI component in subset
1435
Retrieve one or more artifacts associated with each UI component in subset
1440
Render each UI component in subset
1445

FIG. 14

INCREMENTAL MOUNT FRAMEWORK

BACKGROUND

Web pages displayed at a user's device are expected to offer smooth interaction with minimal delay in rendering. That is, web pages should not only load quickly, but also run well. Further, a user should be able to scroll a web page without experiencing jitters to breaks in viewing experience. Most devices today refresh their screens 60 times a second. If the web page being displayed contains an animation or a transition, or the user is scrolling the pages, the browser needs to match the device's refresh rate and put up 1 new picture, or frame, for each of those screen refreshes. Thus, each frame has a budget of about 16 ms (1 second/60=16.67 ms). When a user's device fails to meet this budget, the frame rate drops, and the content judders on screen. This is often referred to as jank, and it negatively impacts the user's experience.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a block diagram showing some of the components typically incorporated in computer systems and other devices on which an incremental mount framework can be implemented.

FIG. **2** is a system diagram illustrating an example of a computing environment in which an incremental mount framework can be utilized.

FIG. **3** is a display diagram illustrating incremental mount of components in accordance with some embodiments.

FIGS. **4**A-**4**C are display diagrams illustrating incremental mount of components in accordance with some embodiments.

FIG. **5** is a display diagram illustrating incremental mount of components in accordance with some embodiments.

FIG. **6** is a display diagram illustrating incremental mount of components in accordance with some embodiments.

FIG. **7** is a display diagram illustrating incremental mount of components in accordance with some embodiments.

FIG. **8** is a display diagram illustrating incremental mount of components in accordance with some embodiments.

FIG. **9** is a display diagram illustrating incremental mount of components in accordance with some embodiments.

FIG. **10** is a display diagram illustrating incremental mount of components in accordance with some embodiments.

FIG. **11** is a flow diagram illustrating a process for a computer system to incrementally mount UI components in accordance with some embodiments.

FIG. **12** is a flow diagram illustrating a process for a computer system to incrementally mount UI components in accordance with some embodiments.

FIG. **13** is a flow diagram illustrating a process for a computer system to recycle incrementally mounted UI components in accordance with some embodiments.

FIG. **14** is a flow diagram illustrating a process for a computer system to recycle incrementally mounted UI components in accordance with some embodiments.

The techniques introduced here may be better understood by referring to the following Detailed Description in conjunction with the accompanying drawings, in which, like reference numerals, indicate identical or functionally similar elements.

DETAILED DESCRIPTION

Overview

As User Interfaces (UIs) become increasingly sophisticated, it gets harder to complete all the rendering work that needs to get done in the time frame allotted to generating each display frame. This proves to be especially challenging with dynamic scrolling surfaces, as new pieces of the UI are constantly being introduced onscreen. Scrollable user interfaces are the dominant paradigm on mobile applications. Traditional mobile applications use components and widgets provided by standard mobile operating systems. For example, mobile applications designed for the Android platform use components such as RecyclerView, CardView, ListView, etc. to implement various UI components in the application. Typically, a list user interface in Android is built by performing the the following steps: using a layout manager to create a layout for the items in the list user interface, and associating the layout to a RecylerView adapter. The layout manager positions item views inside a RecyclerView and determines when to reuse item views that are no longer visible to the user. To reuse (or recycle) a view, the layout manager may ask the RecyclerView adapter to replace the contents of the view with a different element from the dataset. In this manner, RecyclerView is able to display elements from large data sets by creating only enough views to fill the screen and then recycling and reusing them as the UI scrolls. Whenever a new item is about to become visible, RecyclerView recycles or creates the appropriate view, binds the view with the right data, and then finally measure, lay out, and draw it onscreen. While recycling views in this manner improves performance by avoiding the creation of unnecessary views or performing expensive lookups, this approach is not scalable to large lists that involve infinite scrolling. Fitting all these operations within the 16 ms the main thread has to compute a new frame is challenging.

Existing methods are also unable to handle large lists with complex list items without compromising user experience. For example, for a list with infinite scrolling, the existing methods are unable to efficiently recycle views, while ensuring that no frames are dropped while scrolling complex list items (e.g., lists with an unlimited variety of content including shared links, rich text, videos, ads, photos, etc.). Additionally, while existing methods can handle a small number of view types, they are unable to efficiently handle recycling of several different view types, with virtually infinite content variation, in a manner that does not impact the processing and rendering of the various UI components while minimizing jank. As a result, existing methods are unable to consistently deliver smooth scroll performance with complex content. Further, for large scale applications, code changes are made by engineers who collaborate across multiple product teams and deliver code changes every day—thus, it is not sustainable to rely on individual teams to come up with one-off solutions for their own products.

The present disclosure is directed to improve the responsiveness of an application's UI and improve a user's experience, while overcoming the deficiencies of existing methods and frameworks. In some implementations, layout and rendering of UI components in a mobile application are implemented as two independent steps: layout and mount. During the layout step, attributes related to a layout can be identified. For example, during the layout step, a list of UI components in each container, and their respective sizes and positions, can be identified. The layout result is then used in the mount step to create an actual view hierarchy to be

rendered on screen once the component becomes visible. As a result of this decoupling of layout operations from the rendering operations, the CPU-intensive measure and layout operations can be moved to the background thread, saving milliseconds.

The framework described in the present disclosure can also break down complex views into smaller pieces such as text, images, and videos, and render them incrementally, spreading the work that needs to be done across multiple frames. This is especially relevant for complex items that would be very challenging to implement efficiently without a lot of custom optimizations.

The present disclosure further offers a view recycling mechanism where different types of UI components can be recycled from one or more UI component pools. As soon as the inner parts of a composite container move off screen, the framework can make them immediately available for reuse by any other item in the adapter. The recycled components can then be recombined in a virtually infinite number of ways, reducing the total number of views that need to be created and stored in memory. For example, the framework can dynamically cross-pollinate UI components like text and images across all composite containers.

In this way, the framework described in the present disclosure enables the development of complex containers that are able to seamlessly perform layout ahead of time in a background thread and render much flatter view hierarchies that are incrementally mounted using fine-grained recycling, resulting in improved scroll performance. These advantages result in improved scroll performance, better memory behavior with complex views, and easier-to-test UI code.

DESCRIPTION OF FIGURES

The following description provides certain specific details of the illustrated examples. One skilled in the relevant art will understand, however, that embodiments can be practiced without many of these details. Likewise, one skilled in the relevant art will also understand that the present disclosure can include many other obvious features not described in detail herein. Additionally, some well-known structures or functions may not be shown or described in detail below, to avoid unnecessarily obscuring the relevant descriptions of the various examples.

Several implementations are discussed below in more detail in reference to the figures. Turning now to the figures, FIG. **1** is a block diagram illustrating an overview of devices on which some implementations of the disclosed technology can operate. The devices can comprise hardware components of a device **100** that implements an incremental mount framework. Device **100** can include one or more input devices **120** that provide input to the CPU(s) (processor) **110**, notifying it of actions. The actions can be mediated by a hardware controller that interprets the signals received from the input device and communicates the information to the CPU **110** using a communication protocol. Input devices **120** include, for example, a mouse, a keyboard, a touchscreen, an infrared sensor, a touchpad, a wearable input device, a camera- or image-based input device, a microphone, or other user input devices.

CPU **110** can be a single processing unit or multiple processing units in a device or distributed across multiple devices. CPU **110** can be coupled to other hardware devices, for example, with the use of a bus, such as a PCI bus or SCSI bus. The CPU **110** can communicate with a hardware controller for devices, such as for a display **130**. Display **130** can be used to display text and graphics. In some implementations, display **130** provides graphical and textual visual feedback to a user. In some implementations, display **130** includes the input device as part of the display, such as when the input device is a touchscreen or is equipped with an eye direction monitoring system. In some implementations, the display is separate from the input device. Examples of display devices are: an LCD display screen, an LED display screen, a projected, holographic, or augmented reality display (such as a heads-up display device or a head-mounted device), and so on. Other I/O devices **140** can also be coupled to the processor, such as a network card, video card, audio card, USB, firewire or other external device, camera, printer, speakers, CD-ROM drive, DVD drive, disk drive, or Blu-Ray device.

In some implementations, the device **100** also includes a communication device capable of communicating wirelessly or wire-based with a network node. The communication device can communicate with another device or a server through a network using, for example, TCP/IP protocols. Device **100** can utilize the communication device to distribute operations across multiple network devices.

The CPU **110** can have access to a memory **150** in a device or distributed across multiple devices. A memory includes one or more of various hardware devices for volatile and non-volatile storage, and can include both read-only and writable memory. For example, a memory can comprise random access memory (RAM), CPU registers, read-only memory (ROM), and writable non-volatile memory, such as flash memory, hard drives, floppy disks, CDs, DVDs, magnetic storage devices, tape drives, device buffers, and so forth. A memory is not a propagating signal divorced from underlying hardware; a memory is thus non-transitory. Memory **150** can include program memory **160** that stores programs and software, such as an operating system **162**, incremental mount manager **164**, and other application programs **166**. Memory **150** can also include data memory **170** that can include user data such as content or artifacts (e.g., images, videos, strings, URLs, etc.), UI components (e.g., text, list item, image, video, etc.), UI component properties (e.g., text size, title, subtitle, color, font, alignment, width, height, pixel dimension, etc.), layout specifications (e.g., a composite view of components in an immutable layout tree), mount specifications (e.g., a component that can render views or drawables), configuration data, etc., which can be provided to the program memory **160** or any element of the device **100**.

Some implementations can be operational with numerous other general purpose or special purpose computing system environments or configurations. Examples of well-known computing systems, environments, and/or configurations that may be suitable for use with the technology include, but are not limited to, personal computers, server computers, handheld or laptop devices, cellular telephones, wearable electronics, gaming consoles, tablet devices, multiprocessor systems, microprocessor-based systems, set-top boxes, programmable consumer electronics, network PCs, minicomputers, mainframe computers, distributed computing environments that include any of the above systems or devices, or the like.

FIG. **2** is a block diagram illustrating an overview of an environment **200** in which some implementations of the disclosed technology can operate. Environment **200** can include one or more client computing devices **205**A-D, examples of which can include device **100**. Client computing devices **205** can operate in a networked environment

using logical connections **210** through network **230** to one or more remote computers, such as a server computing device.

In some implementations, server **210** can be an edge server which receives client requests and coordinates fulfillment of those requests through other servers, such as servers **220**A-C. Server computing devices **210** and **220** can comprise computing systems, such as device **100**. Though each server computing device **210** and **220** is displayed logically as a single server, server computing devices can each be a distributed computing environment encompassing multiple computing devices located at the same or at geographically disparate physical locations. In some implementations, each server **220** corresponds to a group of servers.

Client computing devices **205** and server computing devices **210** and **220** can each act as a server or client to other server/client devices. Server **210** can connect to a database **215**. Servers **220**A-C can each connect to a corresponding database **225**A-C. As discussed above, each server **220** can correspond to a group of servers, and each of these servers can share a database or can have their own database. Databases **215** and **225** can warehouse (e.g. store) information such as content or artifacts (e.g., images, videos, strings, URLs, etc.), UI components (e.g., text, list item, image, video, etc.), UI component properties (e.g., text size, title, subtitle, color, font, alignment, width, height, pixel dimension, etc.), layout specifications (e.g., a composite view of components in an immutable layout tree), mount specifications (e.g., a component that can render views or drawables), configuration data, etc. Though databases **215** and **225** are displayed logically as single units, databases **215** and **225** can each be a distributed computing environment encompassing multiple computing devices, can be located within their corresponding server, or can be located at the same or at geographically disparate physical locations.

Network **230** can be a local area network (LAN) or a wide area network (WAN), but can also be other wired or wireless networks. Network **230** may be the Internet or some other public or private network. Client computing devices **205** can be connected to network **230** through a network interface, such as by wired or wireless communication. While the connections between server **210** and servers **220** are shown as separate connections, these connections can be any kind of local, wide area, wired, or wireless network, including network **230** or a separate public or private network.

FIG. **3** is a block diagram illustrating components **300** which, in some implementations, can be used in a system employing the disclosed technology. The components **300** include hardware **302**, general software **320**, and specialized components **340**. As discussed above, a system implementing the disclosed technology can use various hardware including processing units **304** (e.g. CPUs, GPUs, APUs, etc.), working memory **306**, storage memory **308** (local storage or as an interface to remote storage, such as storage **215** or **225**), and input and output devices **310**. In various implementations, storage memory **308** can be one or more of: local devices, interfaces to remote storage devices, or combinations thereof. For example, storage memory **308** can be a set of one or more hard drives (e.g. a redundant array of independent disks (RAID)) accessible through a system bus or can be a cloud storage provider or other network storage accessible via one or more communications networks (e.g. a network accessible storage (NAS) device, such as storage **215** or storage provided through another server **220**). Components **300** can be implemented in a client computing device such as client computing devices **205** or on a server computing device, such as server computing device **210** or **220**.

General software **320** can include various applications including an operating system **322**, local programs **324**, and a basic input output system (BIOS) **326**. Specialized components **340** can be subcomponents of a general software application **320**, such as local programs **324**. Specialized components **340** can include layout manager **344**, mounting manager **346**, recycler **348**, visual artifacts manager **350**, and components which can be used for transferring data and controlling the specialized components, such as interface **342**. In some implementations, components **300** can be in a computing system that is distributed across multiple computing devices or can be an interface to a server-based application executing one or more of specialized components **340**.

Layout manager **344** manages and maintains one or more layout views for an application. For example, layout manager **344** can group one or more UI components together in a layout tree that corresponds to a layout view or a container. Based on a layout tree, layout manager **344** can determine a list of UI components and their respective sizes and positions. FIGS. **4** and **5** illustrate various examples of layout views or containers, each comprising multiple UI components. Layout manager **344** can create a layout tree for each layout view or container **405**, **410**, **415**, and/or **510** (FIGS. **4**A-**4**C and FIG. **5**). Layout manager **344** can create a layout tree by first determining a set of UI components in a layout view or container, and then, for each UI component, computing its bounds and other properties, such as the height, width, position, color, etc.

For example, for container **405** (FIG. **4**A), layout manager **344** can create a layout tree which has a root container with two sets of UI components—one in the X direction and a second in the Y direction. The set of UI components in the Y direction comprises an image component **405***a*, and three text components **405***b*, **405***c*, and **405***d*. The set of UI components in the Y direction comprises a horizontal scroll component with at least two image components **405***e* and **405***f*. Layout manager can determine the two different sets of UI components in container **405**. Then, for each UI component in each set, layout manager **344** can determine the bounds (e.g., size and layout), as well as other properties (e.g., font of text, color, resolution, etc.). Size of a UI component can be based on a determined dimension of the UI component in one or more directions (e.g., X direction, Y direction, Z direction, etc.), height property, width property, etc. Layout of a UI component can be based on a set of coordinates (e.g., X, Y, and Z) that indicate a position of the UI component relative to a corner of the display screen, a corner of the app bounds, other components in the container, etc. Types of UI components can include, but are not limited to, text, image, video, horizontal scroll component, vertical scroll component, hyperlink, audio, etc.

Similarly, for container **415**, layout manager **344** can create a layout tree which has a root container with only one set of UI components in the Y direction. FIG. **6** illustrates a layout tree corresponding to container **415** (FIG. **4**C) with an image UI component **610***a*, text UI components **610***b*, **610***c*, **610***d*, and **610***f*, and a video UI component **610***e*. As another example, layout manager **344** can create a layout tree for container **510** (FIG. **5**) by determining a set of UI components in container **510**, and for each UI component, computing its bounds (e.g., size and position) and other properties (e.g., predefined and/or custom properties).

As another example illustrated below, layout manager **344** can create a layout tree which has a root Container with two children stacked horizontally (Row.create) and vertically centered (Align.CENTER). The first child is a SolidColor

component that takes a colorRes prop and has a 40 dp width and height. The second child is a Text component that takes a property named text and fills the remaining horizontal space available in the container using the grow(1f) property.

```
@LayoutSpec
public class MyComponentSpec {
  @OnCreateLayout
  static ComponentLayout onCreateLayout(
      ComponentContext c,
      @Prop int color,
      @Prop String title) {
      return Row.create(c)
          .alignItems(CENTER)
          .child(
              SolidColor.create(c)
                  .colorRes(color)
                  .withLayout( )
                  .widthDip(40)
                  .heightDip(40))
          .child(
              Text.create(c)
                  .text(title)
                  .textSizeRes(R.dimen.my_text_size)
                  .withLayout( )
                  .flexGrow(1f))
          .build( );
  }
}
```

Mounting manager **346** manages the mounting (rendering) of UI components in a container as they become visible on screen. Mounting manager **346** can determine if at least a part of a container is within the bounds of a visible portion of a screen. If at least a part of the container is visible, mounting manager can then determine the specific UI components in the container that are within the visible portion. Based on a scrolling action, only a subset of UI components in a container may actually be visible on the screen. For example, as illustrated in FIG. **7**, for container **710** (which corresponds to container **610** illustrated in FIG. **6**), mounting manager **346** can determine that UI components **710***a*, **710***b*, and **710***c* are not within the bounds of the visible portion of a screen, and that only UI components **710***d* and **710***e* are within the bounds of the visible portion of a screen. Mounting manager **356** can then, for each UI component that is within the bounds of the visible portion of a screen (i.e., UI components **710***d* and **710***e*), retrieve the bounds that were previously computed by the layout manager **344** (e.g., the bounds illustrated in FIG. **6**). Mounting manager **346** can then create an actual view hierarchy to be rendered on the screen by combining the retrieved bounds with one or more artifacts (e.g., text strings, images, videos, etc.) for each UI component that is within the bounds of the visible portion of a screen (i.e., UI components **710***d* and **710***e*). For example, as illustrated in FIG. **8**, mounting manager **346** can combine one or more artifacts **810** (**810***a*, **810***b*, . . . **810***n*) with previously determined bounds of UI components in a container **815** to render/mount an actual view **820** on a screen. Artifacts can be managed and stored by an artifacts manager **350**.

Recycler **348** manages the recycling of UI components. When UI components move off screen, recycler manager can make them immediately available for reuse by other containers. For example, when a portion of a container is no longer within the bounds of the visible portion of a screen, recycler **348** can determine a set of recyclable UI components that are within the portion of the container no longer visible. For each recyclable UI component, recycler **348** clears all references to artifacts of that recyclable specific UI component. For example, when UI components **710***a*, **710***b*, and **710***c* of container **710** (FIG. **7**) are no longer within the bounds of the visible portion of the screen (as illustrated in FIG. **7**), recycler **348** can disassociate the UI components **710***a*, **710***b*, and **710***c* with the artifacts used to render them (e.g., the actual image rendered in UI component **710***a* and the actual text rendered in UI components **710***b* and **710***c*). Recycler **348** can then select a pool of components and add the recycled UI components to the pool. For example, as illustrated in FIG. **9**, when container **905** is no longer within the bounds of a visible portion of a screen, recycler **348** adds the UI components of container **905** to one or more view/drawable pools of components **910**.

FIG. **11** is a flow diagram illustrating a process **1100** for a computer system (e.g., the computing system **100** of FIG. **1**) to incrementally mount UI components in accordance with some embodiments. In particular, the process illustrated in FIG. **11** can be performed as part of the layout step of the incremental mount framework. The process begins at block **1110** where process **1100** determines a set of UI components in a container. For example, for the containers illustrated in FIGS. **4** and **5**, process **1100** can, at block **1110**, determine one or more sets of UI components in each container **405-415** (FIGS. **4**A-**4**C) and **510** (FIG. **5**). The sets of UI components may be determined based on, for example, a direction of view (e.g., a set of UI components in an X direction, a set of UI components in a Y direction, etc.). Other criteria can be used to determine the one or more sets of UI components (e.g., special features/properties of UI components, such as core UI components, optional UI components, etc.).

Then, for each UI component in each set, process **1100** can determine its bounds. For instance, at block **1120**, process **1100** can determine the dimensions (e.g., size, shape, length, width, height, etc.) of each UI component in the set. Process **1100** can, at block **1130**, compute layout, position, and/or other properties of each UI component in the set. Layout and/or position of a UI component can be based on a set of coordinates (e.g., X, Y, and Z) that indicate a position of the UI component relative to a corner of the display screen, a corner of the app bounds, other components in the container, etc. Other properties of a UI component include, but are not limited to, font, color, resolution, user defined properties, border width, padding, margin, offset, etc. At block **1140**, process **1100** can determine if the container has any other unprocessed sets of UI components (i.e., sets of UI components for which the bounds (e.g., dimensions, layout, position, properties, etc.) have not been computed). If any such sets exist (e.g., set of UI components in X direction was processed, but the set of UI components in Y direction was not processed), process **1100** return to block **1110** and repeats one or more steps illustrated in blocks **1110-1140** for any such unprocessed sets. If no unprocessed sets exist, then process **1100** terminates at block **1150**. The result of process **1100** can be a set of UI components and their respective bounds (e.g., dimensions, layout, position, properties, etc.). Process **1100** can be performed for one or more containers, each with different UI components and associated properties.

FIG. **12** is a flow diagram illustrating a process **1200** for a computer system (e.g., the computing system **100** of FIG. **1**) to incrementally mount UI components in accordance with some embodiments. In particular, the process illustrated in FIG. **12** can be performed as part of the rendering step of the incremental mount framework. The process begins at block **1210** when it detects a change in a visible portion of a user interface (e.g., window, screen, etc.). A

change in a visible portion of a user interface can be detected, for example, when a user opens an application, scrolls through an application, switches screens within an application, etc. When a change is detected, at block **1215**, process **1200** determines if at least a portion of a container is within the visible bounds of the user interface. This can be done, for example, by evaluating a visible property for a container. In some implementations, an event can be triggered when a container (or any of its constituent components) becomes visible on a user interface. If no portion of the container is within the visible bounds, process **1200** returns to block **1210** and continues to detect changes in the visible portion of the user interface.

However, if at least a portion of a container is within the visible bounds, at block **1220**, process **1200** determines a subset of UI components in the container that fall within the visible bounds (e.g., a subset comprising UI components **710***d* and **710***e* in FIG. **7**). For example, if a container has two set of UI components (set **1** for an X direction, and set **2** for a Y direction), process **1200** can determine two subsets of UI components (subset **1** from set **1** and subset **2** from set **2**) wherein each UI component in each subset is visible on the user interface. Then, at block **1225**, for each UI component in each subset, process **1200** retrieves its precomputed bounds (e.g., dimensions, layout, position, properties, etc.). At block **1230**, process **1200** can also retrieve one or more artifacts (e.g., text strings, images, videos, etc.) for each UI component that is within the bounds of the visible portion of a screen. For example, at step **1230**, process **1200** can retrieve artifacts **810***a*, **810***b*, . . . **810***n* (FIG. **8**). Process **1200** can then, at block **1235**, render each UI component in each subset using the precomputed bounds and the retrieved artifacts. For example, process **1200** can combine the one or more artifacts **810** (**810***a*, **810***b*, . . . **810***n*) with previously determined bounds of UI components in a container **815** to render/mount an actual view **820** on a screen. The render position of a UI component can be based on the resolution of the user interface.

FIG. **13** is a flow diagram illustrating a process **1300** for a computer system (e.g., the computing system **100** of FIG. **1**) to incrementally mount UI components in accordance with some embodiments. In particular, the process illustrated in FIG. **13** can be performed as part of the recycling step of the incremental mount framework. The process begins at block **1310** where it determines if a portion of a UI component is still within the visible bounds of the screen. If at least a portion of the UI component is still visible, process **1300** stays at block **1310**. However, if no portion of the UI component is within the visible bounds of the screen (e.g., when the user scrolls away completely from the UI component), process **1300** proceeds to block **1315**. At block **1315**, process **1300** clears all references to artifacts associated with the UI component being recycled. For example, when UI components **710***a*, **710***b*, and **710***c* of container **710** (FIG. **7**) are no longer within the bounds of the visible portion of the screen (as illustrated in FIG. **7**), process **1300**, at block **1315** can disassociate the UI components **710***a*, **710***b*, and **710***c* with the artifacts used to render them (e.g., the actual image rendered in UI component **710***a* and the actual text rendered in UI components **710***b* and **710***c*).

At block **1320**, process **1300** determines whether a pool of recycled UI components exists. For example, if this is the first UI component being recycled, a pool of recycled components may not exist (or may be empty). In some implementations, a separate pool for each type of UI component can be maintained. For example, a pool for text UI components, a pool for image UI components, etc. Process **1300** can determine availability of one or more pools based on the type of the component, size of various pools, timestamp when pool was created, etc. If a pool is not available, process **1300** proceeds to block **1325** where a new pool is created. The new pool can be a common pool, or may be designated to be a pool of one or more types of UI components. The newly recycled UI component can then be added to the newly created pool at block **1340**.

On the other hand, if a pool is available, process **1300** determines, at block **1330**, whether the identified pool (or set of pools) have sufficient space for adding the newly recycled UI component. When the identified pool (or set of pools) has sufficient space, the newly recycled UI component, is added to the pool at block **1340**. However, when the identified pool (or set of pools) does not have sufficient space, process **1300** can, at block **1335**, create space for the newly recycled UI component. For example, process **1300** can remove one or more previously recycled components in the pool based on one or more factors such as, timestamp when previously recycled component was added to the pool, popularity of the previously recycled component, complexity of the previously recycled component, etc. Once sufficient space is created, at block **1340**, process **1300** adds the newly recycled UI component to the pool.

FIG. **14** is a flow diagram illustrating a process **1400** for a computer system (e.g., the computing system **100** of FIG. **1**) to recycle incrementally mounted UI components in accordance with some embodiments. In particular, FIG. **14** illustrates the reverse process wherein recycled UI components from a pool of components can be used to render UI components in a second container when at least a part of the second container falls within the bounds of visible portions of a screen. The process begins at block **1410** when it detects a change in a visible portion of a user interface (e.g., screen). When a change is detected, at block **1415**, process **1400** determines if at least a portion of a second container is within the visible bounds of the user interface. This can be done, for example, by evaluating a visible property for the second container. In some implementations, an event can be triggered when the second container (or any of its constituent components) becomes visible on a user interface. If no portion of the second container is within the visible bounds, process **1400** returns to block **1410** and continues to detect changes in the visible portion of the user interface.

However, if at least a portion of a container is within the visible bounds, at block **1420**, process **1400** determines a subset of UI components in the second container that fall within the visible bounds. Then, at block **1425**, for each UI component in each subset, process **1400** identifies a type of the UI component (e.g., text, image, video, header, footer, etc.). At block **1430**, process **1400** can identify one or more pools of recycled UI components for each UI component in each subset. In some implementation, the pool(s) is identified based on the type of the UI component. For example, if the UI component is of a type video, then process **1400** identifies a pool of recycled UI components of type video as a potential source of recycled UI components for the video UI component. In some implementation, different types of UI components may all be part of the same pool of recycled UI components.

When a pool of recycled UI components is identified, process **1400** at block **1435** can retrieve corresponding recycled UI components for one or more UI components in the subset of UI components that are visible on the screen. For example, as illustrated in FIG. **10**, process **1400** can select recycled UI components **1010***a*, **1010***g*, **1010***j*, and **1010***k* from a pool of recycled UI components **1010** for the

UI components in container **1015**. At block **1440**, process **1400** can also retrieve one or more artifacts (e.g., text strings, images, videos, etc.) for each UI component that is within the bounds of the visible portion of a screen. Process **1400** can then, at block **1445**, render each UI component in each subset using the recycled UI components and the retrieved artifacts.

Those skilled in the art will appreciate that the components illustrated in FIGS. **1-13** described above, may be altered in a variety of ways. For example, the order of the logic may be rearranged, substeps may be performed in parallel, illustrated logic may be omitted, other logic may be included, etc. In some implementations, one or more of the components described above can execute one or more of the described processes.

Remarks

The above description and drawings are illustrative and are not to be construed as limiting. Numerous specific details are described to provide a thorough understanding of the disclosure. However, in some instances, well-known details are not described in order to avoid obscuring the description. Further, various modifications may be made without deviating from the scope of the implementations. Accordingly, the implementations are not limited except as by the appended claims.

Reference in this specification to "one implementation," "an implementation," or "some implementations" means that a particular feature, structure, or characteristic described in connection with the implementation is included in at least one implementation of the disclosure. The appearances of the phrase "in some implementations" in various places in the specification are not necessarily all referring to the same implementation, nor are separate or alternative implementations mutually exclusive of other implementations. Moreover, various features are described which may be exhibited by some implementations and not by others. Similarly, various requirements are described which may be requirements for some implementations but not for other implementations.

The terms used in this specification generally have their ordinary meanings in the art, within the context of the disclosure, and in the specific context where each term is used. Terms that are used to describe the disclosure are discussed below, or elsewhere in the specification, to provide additional guidance to the practitioner regarding the description of the disclosure. For convenience, some terms may be highlighted, for example using italics and/or quotation marks. The use of highlighting has no influence on the scope and meaning of a term; the scope and meaning of a term is the same, in the same context, whether or not it is highlighted. It will be appreciated that the same thing can be said in more than one way. One will recognize that "memory" is one form of a "storage" and that the terms may on occasion be used interchangeably.

Consequently, alternative language and synonyms may be used for any one or more of the terms discussed herein, nor is any special significance to be placed upon whether or not a term is elaborated or discussed herein. Synonyms for some terms are provided. A recital of one or more synonyms does not exclude the use of other synonyms. The use of examples anywhere in this specification including examples of any term discussed herein is illustrative only, and is not intended to further limit the scope and meaning of the disclosure or of any exemplified term. Likewise, the disclosure is not limited to various implementations given in this specification.

Those skilled in the art will appreciate that the logic illustrated in each of the flow diagrams discussed above, may be altered in various ways. For example, the order of the logic may be rearranged, substeps may be performed in parallel, illustrated logic may be omitted; other logic may be included, etc.

As used herein, the word "or" refers to any possible permutation of a set of items. For example, the phrase "A, B, or C" refers to at least one of A, B, C, or any combination thereof, such as any of: A; B; C; A and B; A and C; B and C; A, B, and C; or multiple of any item such as A and A; B, B, and C; A, A, B, C, and C; etc.

Without intent to further limit the scope of the disclosure, examples of instruments, apparatus, methods and their related results according to the implementations of the present disclosure are given below. Note that titles or subtitles may be used in the examples for convenience of a reader, which in no way should limit the scope of the disclosure. Unless otherwise defined, all technical and scientific terms used herein have the same meaning as commonly understood by one of ordinary skill in the art to which this disclosure pertains. In the case of conflict, the present document, including definitions will control.

Although the subject matter has been described in language specific to structural features and/or methodological acts, it is to be understood that the subject matter defined in the appended claims is not necessarily limited to the specific features or acts described above. Specific embodiments and implementations have been described herein for purposes of illustration, but various modifications can be made without deviating from the scope of the embodiments and implementations. The specific features and acts described above are disclosed as example forms of implementing the claims that follow. Accordingly, the embodiments and implementations are not limited except as by the appended claims.

Any patents, patent applications, and other references noted above are incorporated herein by reference. Aspects can be modified, if necessary, to employ the systems, functions, and concepts of the various references described above to provide yet further implementations. If statements or subject matter in a document incorporated by reference conflicts with statements or subject matter of this application, then this application shall control.

We claim:

1. A method for incremental display of user interface (Ul) components, comprising:

determining a set of UI components in a container;

for each UI component of at least one of the set of UI components, prior to the UI component entering a visible portion of a user interface, computing, by a background thread of a computing system, bounds of the UI component and storing the computed bounds, wherein the bounds are based on a determined dimension of the UI component in an X direction and a Y direction;

in response to a first change in the visible portion of the user interface:

determining that at least part of the container is within the bounds of the visible portion of the user interface, wherein the part of the container that is within the bounds of the visible portion of the user interface comprises one or more specific UI components of the at least one of the set of UI components; and

for each specific UI component of the one or more specific UI components:

retrieving the previously computed bounds for the specific UI component;

identifying a UI component type for the specific UI component;

identifying, from a plurality of pools of recycled components, a pool of recycled components associated with the identified UI component type, wherein each pool within the plurality of recycled pools is designated for recycled components of a different type;

retrieving, from the pool of recycled components, one or more visual artifacts associated with the specific UI component; and

rendering the specific UI component using the previously computed bounds and the one or more associated visual artifacts;

in response to a second change in the visible portion of the user interface, which is subsequent to the first change:

determining that at least part of the container previously within the bounds of the visible portions of the user interface is no longer within the bounds of the visible portion of the user interface;

determining that a plurality of UI components from the part of the container no longer within the bounds of the visible portion of the user interface are recyclable, the plurality of recyclable UI components comprising a first recyclable component and a second recyclable UI component;

for each of the recyclable UI components:

clearing all references to visual artifacts of the recyclable UI component;

identifying a component type of the recyclable UI component; and

determining whether a pool of recycled components is available for recycled components of the identified component type;

in response to determining that no pool is available for recycled components associated with the identified component type of the first recyclable UI component, creating a new pool of recycled components for recycled components associated with the identified component type of the first recyclable UI component; and

in response to identifying an available pool of recycled components for recycled components associated with the identified component type of the second recyclable UI component, adding the second recyclable UI component to the identified pool of recycled components for the identified component type of the second recyclable UI component.

2. The method of claim **1**, wherein at least one of the set of UI components comprises a horizontal scroll component, a vertical scroll component, or a combination thereof.

3. The method of claim **1**, wherein the bounds of at least one of the set of UI components comprise a pair of coordinates indicative of a position of the UI component relative to a corner of the user interface.

4. The method of claim **1**, wherein a render position of at least one of the set of UI components is based on an image resolution of the user interface.

5. The method of claim **1**, wherein the container comprises a set of UI components in the X direction and a set of UI components in the Y direction.

6. The method of claim **1**, wherein the plurality of pools of recycled components comprises at least one of a pool for text UI components or a pool for image UI components.

7. The method of claim **1**, wherein prior to adding the second recyclable UI component to the identified pool of recycled components for the identified component type of the second recyclable UI component:

determining whether the identified pool of recycled components, for the identified component type of the second recyclable UI component, has space for the second recyclable UI component; and

when the identified pool of components does not have space for the second recyclable UI component, removing at least one recyclable UI component from the identified pool of components.

8. The method of claim **7**, wherein the at least one recyclable UI component is removed from the identified pool of components based on at least one of a popularity metric or a complexity metric.

9. The method of claim **7**, wherein the at least one recyclable UI component is removed from the identified pool of components based on a timestamp of when the at least one recyclable UI component was added to the identified pool of components.

10. A system for incremental display of user interface (UI) components on a user interface, the system comprising:

at least one processor; and

at least one memory, coupled to the at least one processor, and carrying instructions that, when executed by the at least one processor, cause the system to perform operations comprising:

determining a set of UI components in a container;

for each UI component of at least one of the set of UI components, prior to the UI component entering a visible portion of the user interface:

computing, by a background thread executed by the processor, bounds of the UI component, wherein the bounds are based on a determined dimension of the UI component in an X direction and a Y direction; and

storing the computed bounds of the UI component; and

in response to a first change in the visible portion of the user interface:

determining that at least part of the container is within the bounds of the visible portion of the user interface, wherein the part of the container that is within the bounds of the visible portion of the user interface comprises one or more specific UI components of the at least one of the set of UI components; and

for each specific UI component of the one or more specific UI components:

retrieving the previously stored bounds for the specific UI component;

identifying a UI component type for the UI component;

identifying, from a plurality of pools of recycled components, a pool of recycled components associated with the identified UI component type, wherein each pool within the plurality of recycled pools is designated for recycled components of a different type;

retrieving, from the pool of recycled components, one or more visual artifacts associated with the specific UI component; and

rendering the specific UI component using the previously stored bounds and the one or more associated visual artifacts;

in response to a second change in the visible portion of the user interface, which is subsequent to the first change:

determining that at least part of the container previously within the bounds of the visible portions of the user interface is no longer within the bounds of the visible portion of the user interface;

determining that a plurality of UI components from the part of the container no longer within the bounds of the visible portion of the user interface are recyclable, the

plurality of recyclable UI components comprising a first recyclable component and a second recyclable UI component;

for each of the recyclable UI components:

clearing all references to visual artifacts of the recyclable UI component;

identifying a component type of the recyclable UI component; and

determining whether a pool of recycled components is available for recycled components of the identified component type;

in response to determining that no pool is available for recycled components associated with the identified component type of the first recyclable UI component, creating a new pool of recycled components for recycled components associated with the identified component type of the first recyclable UI component; and

in response to identifying an available pool of recycled components for recycled components associated with the identified component type of the second recyclable UI component, adding the second recyclable UI component to the identified pool of recycled components for the identified component type of the second recyclable UI component.

11. The system of claim **10**, wherein at least one of the set of UI components comprises a horizontal scroll component, a vertical scroll component, or a combination thereof.

12. The system of claim **10**, wherein the bounds of at least one of the set of UI components comprise a pair of coordinates indicative of a position of the UI component relative to a corner of the user interface.

13. The system of claim **12**, wherein a render position of at least one of the set of UI components is based on an image resolution of the user interface.

14. The system of claim **10**, wherein the container comprises a set of UI components in the X direction and a set of UI components in the Y direction.

15. The system of claim **10**, wherein the plurality of pools of recycled components comprises at least one of a pool for text UI components or a pool for image UI components.

16. The system of claim **10**, wherein a render position of at least one of the set of UI components is based on an image resolution of the user interface.

17. A non-transitory computer-readable storage medium storing instructions that, when executed by a computing system, cause the computing system to perform operations for incremental display of user interface (UI) components on a user interface, the operations comprising:

for each UI component of at least one of a set of UI components in a container, prior to the UI component entering a visible portion of the user interface, computing, by a background thread of a computing system, bounds of the UI component and storing the computed bounds, wherein the bounds are based on a determined dimension of the UI component in an X direction and a Y direction;

in response to detecting a first change in the visible portion of the user interface:

determining that at least part of the container is within the bounds of the visible portion of the user interface, wherein the part of the container that is within the bounds of the visible portion of the user interface comprises one or more specific UI components of the at least one of the set of UI components; and

for each specific UI component of the one or more specific UI components: retrieving the previously computed bounds for the specific UI component;

identifying a UI component type for the specific UI component;

identifying, from a plurality of pools of recycled components, a pool of recycled components associated with the identified UI component type, wherein each pool within the plurality of recycled pools is designated for recycled components of a different type;

retrieving, from the pool of recycled components, one or more visual artifacts associated with the specific UI component; and

rendering the specific UI component using the previously computed bounds and the one or more associated artifacts;

in response to detecting a second change in the visible portion of the user interface, which is subsequent to the first change:

determining that at least part of the container previously within the bounds of the visible portions of the user interface is no longer within the bounds of the visible portion of the user interface;

determining that a plurality of UI components from the part of the container no longer within the bounds of the visible portion of the user interface are recyclable, the plurality of recyclable UI components comprising a first recyclable component and a second recyclable UI component;

for each of the recyclable UI components:

clearing all references to visual artifacts of the recyclable UI component;

identifying a component type of the recyclable UI component; and

determining whether a pool of recycled components is available for recycled components of the identified component type;

in response to determining that no pool is available for recycled components associated with the identified component type of the first recyclable UI component, creating a new pool of recycled components for recycled components associated with the identified component type of the first recyclable UI component; and

in response to identifying an available pool of recycled components for recycled components associated with the identified component type of the second recyclable UI component, adding the second recyclable UI component to the identified pool of recycled components for the identified component type of the second recyclable UI component.

18. The non-transitory computer-readable storage medium of claim **17**, wherein determining that one or more specific UI components of the at least one of the set of UI components in the container is within the bounds of the visible portion of the user interface is based on evaluating a visible property of each specific UI component of the one or more specific UI components.

19. The non-transitory computer-readable storage medium of claim **17**, wherein the container comprises a set of UI components in an X direction and a set of UI components in a Y direction.

20. The non-transitory computer-readable storage medium of claim **17**, wherein at least one of the set of UI

components comprises a horizontal scroll component, a vertical scroll component, or a combination thereof.

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